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SYSTEMATIC VIDEO RECORDING OF SEATED ATHLETES DURING THE SHOT-PUT EVENT AT THE SYDNEY 2000 PARALYMPIC GAMES

Video recording of elite seated shot putters during world-class events

Keywords: sports biomechanics, video recording, field event, shot-put, disability

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Abstract

The purpose of this paper is to share useful and practical information coming out of the first experience of systematic video recording of seated shot-putters during the Sydney 2000 Paralympic Games. It is anticipated that this paper will provide valuable information to sport scientists facing the challenge of conducting performance analysis of able-bodied or disabled athletes, such as seated shot-putters, during world-class competitive events. More specifically, this paper provides (1) the practical aspects of the cameras' setup used during this systematic video recording, (2) the number and usability of attempts recorded, taking into consideration the impact of uncontrollable perturbing factors, and (3) recommendations to improve the video recording procedure in such conditions. Two operators recorded each put using two compact, high-speed digital video cameras placed in different locations such as right, left or front of the shot-putter. In this study, 15% of the attempts were not recorded, 72% were recorded and fully available for analysis, 10% were incomplete and 2% were obstructed (as a percentage of expected attempts). This study suggests that the increase of the number and usability of the attempts recorded relies on the number and position of cameras and the operators as well as on other facilitating actions.

Introduction

Video recording is the central element of biomechanical analyses based on kinematic data including the range of motion, the linear and angular momentum of each segment as well as the mechanical energy expended. As for all top athletes, kinematic analysis is particularly important for the elite seated shot-putters because it is one of the rational means available that could be used to improve the understanding of their performance. More specifically, athletes, coaches and sports scientists can exploit this data to improve the shot-put technique and the design of the throwing seat.

Video recording during training

Currently, this understanding is only based on video recording of emerging and elite shot-putters during training (Chow and Mindock, 1999, Chow et al., 2000). On one hand, the recording in this situation presented the advantage of easily accommodating usual experimental requirements including the use of active or passive markers, the positions of cameras, the number of attempts recorded, etc. One the other hand, the data collected during training was partially representative of the technique as performed by these elite athletes while competing in a world-class event. This is mainly because elite athletes do not perform at their best, let alone break a world record, during training sessions particularly during the early stage of the preparation for a major event. For instance, the elite shot-putters participating to the Chow et al.'s, 2000 study performed on average 15±9% less than their personal best.

Video recording during world-class competition

Consequently, a sound understanding of the performance of elite seated shot-putters would require a performance analysis based on video recording during a world-class competition. This should allow sports scientists to produce a systematic and more realistic biomechanical analysis. Here, the term "systematic" refers to the recording of all attempts performed by a target group of athletes, such as a class. During a world-class competition every attempt of each athlete must be recorded in order to capture the best put, which is known only at the end of the event. The data collected in these circumstances is more realistic because it takes into consideration a number of external factors influencing the performance. These factors include the stress and pressure due to the presence of other opponents, mass-media, referees in charge of applying the strict rules as well as the use of official equipment to anchor the throwing seat (use of metal plate on the ground rather than pegs), travelling fatigue, etc.

Benefits of video recording during world-class competition

Furthermore, coaches, athletes and sports scientists, as well as classifiers and referees, could benefit from a kinematic analysis based on video recording of elite seated shot-putters during world-class events as the outcomes of such analysis have the potential to enhance performance and increase the fairness of the event (classification and judging).

Coaches and elite shot-putters use video recording regularly during training. Therefore, conducting similar recording during the actual competition is of value to complement their observations obtained during training. Furthermore, the understanding of the actual performance of World Championship and Paralympic medallists could not only contribute to improve both training methods and seat design but also the curricula of existing courses in training and coaching as well as the talent identification system.

Classifiers divide disabled athletes into classes according to their gender and functional level or "movement potential" depending on the control and strength of various muscle groups. This process involves observation of athletes during the event as well as a physical and functional examination assessing muscle power, range of joint movement, backwards and forwards movement, side to side movement and trunk rotation (Higgs et al., 1990, McCann, 1993, Vanlandewijck and Chappel, 1996, Williamson, 1997, Laveborn, 2000, Tweedy, 2002). A video recording of the athletes during the actual event and subsequent kinematic analysis could provide the classifiers with more accurate and true information about the athletes' functional level as the actual range of motion of the trunk, for instance, can be quantified. Currently, there is no set video recording procedure during the event aimed at determining this true range of motion of the athletes as well as their true compliance during the classification process. In addition, video recording during the event can show if the athletes' technique follows the rule, indicating that the shot cannot move behind the line defined by the shoulder and the ear. Therefore, the recordings could be used as a medium to settle protests of athletes against referees' decisions. This aspect was experienced during the Sydney 2000 Paralympic Games where the tapes used in the following study were required on several occasions by referees needing to review their decision.

Implementation of video recording during world-class competition

Theoretical aspects of successful 2-D or 3-D performance analysis of an athletic technique using video recording in experimental conditions have been previously described in detail (Marzan, 1975, Allard, 1995). Some elements of video recording settings during world-class competition could be found for able-bodied shot-putters (Ariel, 1973, Ariel, 1979). However, these elements were not fully relevant since the seated shot-putters use a different technique from the one used by able-bodied athletes. A few studies included key elements of video recording of seated athletes but only in a training environment (Chow and Mindock, 1999, Chow et al., 2000).

While the general principles presented in these articles might be applied to video recording of seated shot-putters during world-class events, adaptations may be required to compensate for the many extra constraints imposed on such data collection, especially if the recording is required to be systematic. For example, a retake of a performance is impossible and every attempt of each athlete must be recorded in order to capture the best puts, which is known only at the end of the event. The recording cannot interfere in any way with the athletes, the officials, the referees or the TV crews. For instance, no active or passive markers may be placed on the athlete. The camera views can be obstructed at any time by several factors such as broadcast TV crews, referees and equipment. Contacts between the operators of the cameras are limited, as no radio communication may be allowed in the stadium. Furthermore, the number of cameras is limited and their position should not interfere with any of the other on-going sporting events.

The systematic video recording of seated shot-putters during actual world-class competition might be eased by the development of discrete, affordable and user-friendly video recording systems matching the requirement of scientific measurements. Most of these systems use two or more compact, high-speed, digital video cameras allowing at least a bi-planar analysis. The use of compact cameras is important for recording in the conditions of a world-class event since the space available is limited. Furthermore, such cameras are not confused with TV cameras, which could be moved on demand. These compact cameras allow transfer of data recorded in a digital format directly onto the computer and avoids the time consuming digitizing process that can lead to a loss of quality of the data. These cameras could acquire data at a rate ranging up to 100 Hz, which should allowed sport scientists to accurately determine the key events of the put (e.g. end of back thrust, instant of release of the shot). This aspect is particularly important since the accuracy of determining the instant of release of the shot is critical in establishing the initial parameters of the shot's trajectory including the velocity, angle and height of release (Lichtenburg and Wills, 1978, Linthome, 2001).

Need for practical information

The benefits and key elements of the implementation (general principles and technical means available) of the video recording during world-class events have been provided. Nevertheless, there is yet a lack of studies presenting the technical aspects and the outcomes of such video recording.

However, a systematic video recording of seated shot-putters participating in world-class competition was conducted for the first time during the Sydney 2000 Paralympic Games. The primary aim of this recording was to show the principles underlying elite seated shot-putters' performance. The secondary aim was to determine the true compliance of the athletes during the classification process. These were achieved using a bi-planar kinematic analysis.

The knowledge and understanding of the perturbing factors listed above were essential in the planning of this video recording. However, the literature review conducted in preparation for this systematic video recording revealed that useful and practical information was only partially available. Furthermore, no studies provided information on how to prevent and accommodate these factors as well as their potential impact on camera setup, and the number and usability of attempts recorded.

In conclusion, the literature review brought to light a need for practical information for successful systematic video recording during world-class competitions.

Purposes

A number of unforeseen difficulties not presented in the literature or listed above were encountered during this initial experience of systematic video recording. Consequently, it was considered desirable to detail these problems so as to recommend protocols to circumvent them at future events.

While the outcomes of the biomechanical analysis as such will be the focus of following articles, the ultimate purpose of this present paper is to share essential and practical information from this experience. This will provide useful benchmark data and guidelines for similar future systematic video recording of the performance of able-bodied and disabled athletes during any world-class event.

The specific purposes of this paper are to provide:

1. The practical aspects of camera setup for use during the systematic video recording of seated shot-putters suited to kinematic analysis, as well as the location and the field of view of the cameras. This will include essential information about the camera setup for future video recording of seated shot-putters during world-class competition.
2. The number and the usability of attempts recorded taking into consideration the impact of uncontrollable perturbing factors. This will indicate the amount of usable data that one can expect to collect during world-class competition.
3. Recommendations to improve the number and the usability of attempts recorded in the conditions of a world-class competition. This section will focus on the camera setup, the number of operators and the reduction of perturbing factors. This will provide a practical guideline for future similar studies.

Method

The video recording as described below aimed to underlie the specific aspects of the elite seated shot-putters performance such as the parameters of the shot's trajectory and the segmental actions of the athletes (Ariel, 1973, Dessureault, 1978, Lichtenburg and Wills, 1978, Ariel, 1979, Zatsiorsky et al., 1981, McCoy, 1984, Sušanka, 1990, Bartonietz and Borgström, 1995, Tsirakos, 1995, Luhtanen et al., 1997, Chow et al., 2000, Linthome, 2001).

This method could not employ markers on the athletes or any other direct interference with them during the attempt.

Participants

A total of 93 seated shot-putters participating in the Sydney 2000 Paralympic Games were selected from 10 classes (F52 to F58) accordingly to the International Stoke Mandeville Wheelchair Sports Federation (ISMWSF) classification system (Laveborn, 2000). This included 30 women (7 in F52-F54, 5 in F55, 10 in F57, 8 in F58) and 63 men (13 in F52, 9 in F53, 13 in F54, 7 in F55, 10 in F56, 11 in F57). The classes F52 and F54

women were grouped together due to the lack of athletes in each class.
The informed consent for each athlete to participate in this study was obtained through the International Paralympic Committee (IPC).

Camera setup for bi-planar video recording

Ideally, a complete understanding of the action of the body segments and the parameters of the shot's trajectory requires a three-dimensional kinematic analysis as it provides the actual position and orientation of a given segment in relation to another. In principle, a marker or a given anatomical body landmark must be seen simultaneously by at least two and preferably more cameras in order to be reconstructed and used in subsequent three-dimensional kinematic analysis (Abdel-Aziz and Karara, 1971, Marzan, 1975). Consequently, a three-dimensional kinematic analysis of elite shot-putters will necessitate at least four cameras aligned diagonally with each corner of the plate and preferably a fifth one located above the athlete. While this setup appears trouble-free to implement in an experimental framework, it is not suitable and practical for the real events in the field. It is unrealistic to expect that the field of view of each camera on the floor will not be obstructed during the recording of the attempt since about 30 people work in the throwing area alone. Furthermore, it means that accreditations for up to five camera operators must be obtained from the IPC whose aim is to reduce the number of people working in the area.
Consequently, it is more realistic to attempt a bi-planar analysis under these types of environments. Using two cameras appeared to be a more suitable option because it was less invasive than a three-dimensional analysis and still allowed kinematic analysis in the sagittal and frontal planes which will provide a fair representation of the main rotation between the shoulders and the hips of the athletes. Most of these athletes are seated facing the sector and their putting action occurs essentially in the sagittal plane. As no passive or active markers are allowed on the athlete, automatic tracking could not be used. Thus, the two-camera setup has the advantage of reducing the data that needed to be digitized manually or pointed frame-by-frame. In addition, this method was more cost effective as it required only accreditation for two operators and fewer airfares as well as less time for computing.
The following sections will present the key aspects of the camera setup including the type, the location and the field of view of the cameras.

Type of cameras

Two operators recorded each put using two compact (20 x 20 x 10 cm), high-speed digital video cameras (JVC, Model DVL 9800) set at a sample rate of 100 Hz.

Location of the cameras

*** Insert Figure 1 here ***

The two cameras were operated simultaneously with one camera on the side and the other in front of the athlete as illustrated in Figure 1, for most of the classes. The camera on the side was placed either on the right or the left of the athlete depending on their throwing hand for the classes F52-F54 and F58 Women. Previous studies placed the second camera behind the thrower (Dessureault, 1978, Chow and Mindock, 1999, Chow et al., 2000). At the Sydney 2000 Paralympic Games, the rear of the plate was a designated area for athletes, assistants and referees and was therefore not accessible. For this reason, the second camera was located in front of the thrower for this study.
A slightly different setup was used for a few classes when the object of research was concerned with a specific aspect of the technique. For example, only one camera was placed in the front for the classes F58 Women, F57 Men and F57 Women since only the rotation in the frontal plane of the athletes in these classes was of interest. Also, the cameras were placed on each side for the class F56 Men in order to accurately determine the position of the upper body segments in the sagittal plane of both sides of the athletes in this class.
A customized calibration frame (2 m length x 1.5 m height x 1 m width) including 43 control points was recorded at the beginning and at the end of each event.

Field of view and position of the cameras

A few pilot studies conducted prior to the Games defined the suitable cameras' field of view for data analysis including displacements in sagittal and frontal planes of each body segment as well as the determination of the shot's trajectory. For both cameras, the bottom of the field of view included the full-length (2.29 m) and full-width (1.68 m) of the plate on the ground, used to secure the athlete's seat. The field of view in the sagittal plane (camera on the side) was enlarged in the direction of the throw to secure the recording of at least the first five frames of the shot's aerial trajectory (Figure 2). In experimental or training conditions, these fields of view can be obtained by zooming to reduce the perspective error once the cameras were placed at distance from the plate. During this study, the zoom was occasionally used to achieve the appropriate field of view, particularly for the camera in the frontal plane, which had to be placed outside of the sector. The camera on the side was placed relatively closer to the plate in order to reduce the possibilities of intrusion of TV crews, equipment and/or referees in the field of view.

The camera in front of the thrower was placed between 14 to 18 m perpendicular to the width of the plate, while the camera on the side was between 8 to 10 m perpendicular to the length of the plate. The height of both cameras was approximately 1.10 m. The angle between the optical axis of the two cameras and the ground was approximately 90^0. The positions of the cameras in relation to the plate are presented in Figure 1.

The pixel resolution ranged between 0.95 cm to 1.35 cm for both cameras depending on their positions, which provided sufficient accuracy for further analysis.

Duration of recording

The duration of the recording of each attempt was approximately 7 seconds. The recording started when the referee handed the shot to the athlete, and ended when the shot landed on the ground. Consequently, the recording included the back and forward thrusts of preparation as well as the delivery of the shot. An overall of approximately 100 minutes worth of data was recorded for each camera.

Results and discussion

*** Insert Table 1 here ***

*** Insert Figure 2 here ***

Table 1 reports the number of useful attempts recorded, taking into consideration the effect of uncontrollable perturbing factors. This table details the number and the percentage of attempts recorded, not recorded, incomplete, obstructed and usable for both cameras in each class. The percentages are expressed with regard to the total number of attempts expected in each class. This number of attempts expected was determined by the number of athletes and the number of attempts each athlete was allowed to perform according to competition rules (three attempts in the qualification round for all athletes and three further attempts in the final round for athletes ranked in the first six from the qualification round).

Number of attempts recorded

A total of 717 attempts performed by 93 seated athletes from 10 classes was recorded resulting in an average of 88±13% of the expected attempts recorded per class.

One hundred and thirty two attempts, corresponding to an average of 12±13% of the expected attempts, were not recorded. The number of attempts not recorded is particularly important for the F52 Men and F54 Men classes for both cameras. The qualification round of these classes took place on two separate pits because the number of participants exceeded 12 (13 for F52 Men and 14 for F54 Men). This aimed at reducing the duration of the event for these classes. The operator was unable to record 30 attempts in class F56 Men as the position of a referee completely obstructed the view of the athletes as shown in the example in Figure 2. Overall, 20 attempts corresponding to 2.35% of the attempts expected were not recorded by the operator who was under the impression that the first attempt was a warm up.

Usability of the attempts recorded

Here, the term ‘usability’ refers to the potential use of the recording for a complete tracking of the body landmarks for at least five frames before the beginning of the back thrust and after the release of the put.

There were 614 attempts successfully recorded and fully useable for further analysis, corresponding to an average of 74±23% of the expected attempts. The difference between the number of attempts recorded and those useable was due to the number of attempts either incomplete or obstructed.

An attempt was defined as “incomplete” when it was only partially recorded mainly when the operators triggered the acquisition slightly after the beginning of the put. This occurred while the operators were distracted due to an unforeseen event, or when the athletes put the shot immediately without preparation. This occurred during 16 attempts corresponding to 2% of the attempts expected. The number of attempts incomplete was more important for the camera on the side because the operator was more prone to be distracted by people moving around and in front of the camera.

An attempt was defined as “obstructed” when a part of the athlete’s movement was hidden during the put. The camera in the frontal plane was only obstructed for 14 attempts mainly due to TV crews in the field of view. The camera in the sagittal plane was obstructed almost twice as often. Here, one source of obstruction was equipment such as the posts for the safety net used during the discus event, display panels, tables for referees and boxes. As illustrated in Figure 2, the other source of obstruction was the referees. Some puts were obstructed either at the beginning or at the end by the referee who was required to be perpendicular to the athlete so as to have a proper appreciation of their technique (F52-F54 Women, F54 Men).

However, the incomplete or obstructed attempts might be partially useable for further analysis. For example, the parameters of the shot's trajectory might be determined for the attempts incomplete or obstructed at the beginning while the analysis of the segmental organisation might be impossible. Therefore, the realistic number of attempts useable for analysis was close to 85% of the expected attempts.

Conclusion

In this study, 15% of the attempts were not recorded, 72% were recorded and fully available for analysis, 10% were incomplete and 2% were obstructed (as a percentage of expected attempts).

While these figures may appear satisfactory in the context of training, they might not be considered acceptable for a competition event, particularly if the recording of the attempts performed by the medallists was incomplete or obstructed. For instance, this could jeopardise a study aiming at analysing the technique of the best athletes.

The measures to improve the capture rate emanating from this first experience of systematic video recording during a world-class event are linked to the number and position of the cameras as well as the number of operators.

Number and position of the cameras

It is shown that two cameras were sufficient to produce a systematic video recording for classes with fewer than 12 athletes. However, two additional cameras would be needed for a systematic video recording of classes exceeding 12 athletes as two or more separate pits might be used simultaneously.

It has been demonstrated that it is practical and efficient to place one camera in front of the thrower. The recordings of this camera were less frequently obstructed than those of the side camera. The side camera can be placed on the right of the thrower on most occasions since only four athletes representing less than 6% of all participants were left-handed.

In addition, one may need to compromise the ideal position and remote distance of the camera from the plate (proper field of view with zoom) as this space is likely to be occupied because it overlaps with other events (e.g. other throwing pits or racing track). Our experience demonstrated that the further the cameras were positioned from the plate, the higher the chances of perturbing factors, such as someone walking in front of the cameras.

Number of operators

Video recording in the conditions of world-class competition will always have unpredictable factors, involving the officials, equipment and broadcast TV crews. This is mainly because the work of the officials and broadcast TV crews traditionally and legitimately prevails over a research project. One way to significantly reduce the number of attempts incomplete or obstructed due to these unpredictable factors is to allow the operator to prevent them.

During the video recording, attempts were made to use the remote control to trigger the recording at a distance. This way the operator could start the recording and potentially prevent interferences of the environment. The operator stood nearby the camera and paid particular attention to the surrounding. However, in our experience this strategy generally failed. It did not reduce the number of obstructions and eventually made the triggering of the recording more difficult.

Our experience showed that a better way to prevent interferences of the environment during the recording is to employ an additional operator per camera, particularly on the side camera. Only one operator per camera conducted the video recording in this study. However, another operator could have prevented officials or other people from walking within the field of view. In addition, this would leave the operator behind the camera in a better position to follow the event and closely concentrate on the recording. Furthermore, the operators could take turns conducting the recording and this way the operator behind the camera might be able to maintain the necessary level of concentration required over the three to four hour duration of the event.

Additional facilitating actions

Our experience revealed that a few other actions might help to improve the video recording, such as providing the participants with an informative document and defining a protected zone.

Officials and broadcast TV crews were formally informed prior each event. They were both most sensitive and cooperative during the video recording sessions. However, it is likely that providing more formal information in advance about the study will increase their awareness and therefore reduce the number of attempts that were incomplete or obstructed in future event. For example, a one-page flyer could be provided to them, via the IPC, prior to the event, informing them of the recording process and its benefits.

In addition, lines corresponding to the field of view of the camera on the side could be drawn on the ground and presented as a sensitive zone. Such a display might help the participants to be more aware of their position in relation to the camera. However, this required prior approval from the organising committee and officials.

Practical implication for further performance analysis during world-class event

It could be concluded from our experience that the guideline for future bi-planar systematic video recording of seated shot-putters during world-class events should include the following key points:

- Assess thoroughly the feasibility of the cameras' positions prior to opt for a three-dimensional video recording setup,
- Use at least two cameras and preferably four cameras for a bi-planar analysis,
- Place the cameras reaching the relevant field of view as close as possible to the plate,
- Employ two operators per camera. One in charge of the recording while the other prevents interferences from the environment,
- Provide formal information on the study to officials and broadcast TV crews prior to the event,
- Draw a line on the ground corresponding to the field of view of the cameras.

It is hoped that this paper will provide valuable information to the sports scientists facing the challenge of conducting performance analysis based on systematic video recording of able-bodied or disabled athletes, such as seated shot-putters, during world-class competitive events.

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Table 1 Breakdown of the success rate for systematic video recording of the shot-put event by class.

				Not recorded		**Recorded**								
						Total		**Incomplete**		**Obstructed**		**Useable**		
Class	**Gender**		**Expected**	**#**	**% (2)**	**#**	**% (2)**	**#**	**% (2)**	**#**	**% (2)**	**#**	**% (2)**	
Camera located in front (1)														
F52-F54	Women		42	1	2	41	98	0	0	5	12	36	86	
F55	Women		30	0	0	30	100	0	0	2	7	28	93	
F57	Women		54	1	2	53	98	5	9	0	0	48	89	
F52	Men		63	21	33	42	67	0	0	1	2	41	65	
F53	Men		51	3	6	48	94	0	0	1	2	47	92	
F54	Men		63	18	29	45	71	0	0	0	0	45	71	
F55	Men		42	1	2	41	98	0	0	5	12	36	86	
F57	Men		57	1	2	56	98	2	4	0	0	54	95	
		Total	**402**	**46**		**356**		**7**		**14**		**335**		
		Mean			**10**		**90**		**2**		**4**		**85**	
		SD			**13**		**13**		**3**		**5**		**11**	
Camera located in side (L: Left, R: Right, L/R: Left or right) (1)														
F52-F54	Women	L/R	42	5	12	37	88	0	0	10	24	27	64	
F55	Women	R	30	0	0	30	100	3	10	0	0	27	90	
F58	Women	L/R	48	4	8	44	92	1	2	31	65	12	25	
F52	Men	R	63	21	33	42	67	1	2	22	35	19	30	
F53	Men	R	51	3	6	48	94	3	6	0	0	45	88	
F54	Men	R	63	22	35	41	65	1	2	5	8	35	56	
F55	Men	R	42	1	2	41	98	0	0	0	0	41	98	
F56	Men	R	54	19	35	35	65	0	0	1	2	34	63	
F56	Men	L	54	11	20	43	80	0	0	4	7	39	72	
		Total	**447**	**86**		**361**		**9**		**73**		**279**		
		Mean			**17**		**83**		**2**		**16**		**65**	
		SD			**14**		**14**		**3**		**22**		**25**	

(1) Regarding to the thrower **(2) Percentage of expected attempts**

Figure 1 Position of the cameras in relation to the plate

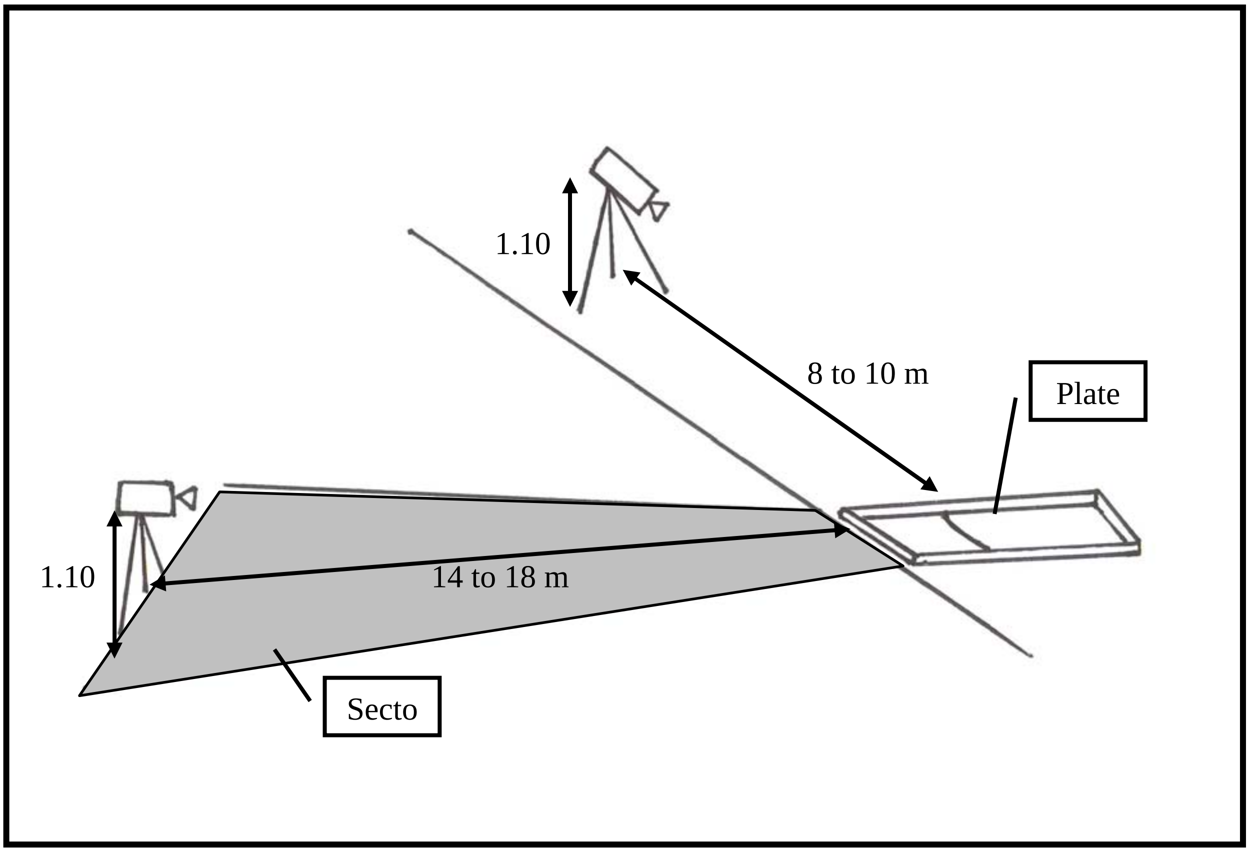

Figure 2 Example of the field of view for the side camera and an obstruction caused by a referee.